The first Definition of capacity applies only for binary symmetric channels, and represents the number of bits/transmission. The second result states capacity more generally, having units of bits/second. How would you convert the first definition's result into units of bits/second?

Example 6.5

The telephone channel has a bandwidth of 3 kHz and a signal-to-noise ratio exceeding 30 dB (at least they promise this much). The maximum data rate a modem can produce for this wireline channel and hope that errors will not become rampant is the capacity.

$$\begin{aligned} C &= 3 \times 10^3 \log_2(1 + 10^3) \\ &= 29.901\ kbps \end{aligned}$$

(6.62)

Thus, the so-called 33 kbps modems operate right at the capacity limit.

Note that the data rate allowed by the capacity can exceed the bandwidth when the signal-to-noise ratio exceeds 0 dB. Our results for BPSK and FSK indicated the bandwidth they require exceeds

$$\frac{1}{T}$$

What kind of signal sets might be used to achieve capacity? Modem signal sets send more than one bit/transmission using a number, one of the most popular of which is **multi-level signaling**. Here, we can transmit several bits during one transmission interval by representing bit by some signal's amplitude. For example, two bits can be sent with a signal set comprised of a sinusoid with amplitudes of

$$\pm A\ and\ \pm (\frac{A}{2}).$$

6.32 Comparison of Analog and Digital Communication

Analog communication systems, amplitude modulation (AM) radio being a typifying example, can inexpensively communicate a bandlimited analog signal from one location to another (point-to-point communication) or from one point to many (broadcast). Although it is not shown here, the coherent receiver (Figure 6.6) provides the largest possible signal-to-noise ratio for the demodulated message. An analysis (Section 6.12) of this receiver thus indicates that some residual error will **always** be present in an analog system's output.

Although analog systems are less expensive in many cases than digital ones for the same application, digital systems offer much more efficiency, better performance, and much greater flexibility.

- **Efficiency**: The Source Coding Theorem allows quantifcation of just how complex a given message source is and allows us to exploit that complexity by source coding (compression). In analog communication, the only parameters of interest